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Synthetic Organic Chemicals

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Organic Chemicals as Plant Growth Stimulants

THE stimulating effect of organic chemicals on plant growth has recently attracted considerable attention. The well-known action of fertilizers in furnishing food to the growing plant is one of the oldest examples of the use of chemicals in connection with agricultural problems. Soil investigators have long recognized, however, that there are effects obtained from manure which are not due to the inorganic fertilizers present. Recent findings throw considerable new light on this problem, showing that certain organic substances in minute quantities have a definite and formative effect on the growth and development of plants.

These chemicals in many cases are not complex compounds as might be expected. Such simple organic substances as ethylene, acetylene, propylene, and carbon monoxide bring about astonishing results when plants are subjected to traces of these gases in air. One of the most interesting effects is that of ethylene on the green rind of ripe citrus fruits. The chlorophyll pigments which for some unknown reason are retained in the rind are changed by the presence of this gas in air, resulting in the normal lemon or orange color, which, so far as the purchaser is concerned, indicates ripeness.

These same gases are found to cause epinasty of leaves and to induce adventitious roots to form on stems and leaves of plants which have been exposed to traces of them. Sensitive plants, such as the tomato, sunflower, etc., are affected by quantities too small to be detected by chemical methods. Use is made of this property to detect the presence of illuminating gas, in which ethylene is present, in greenhouses, living rooms, etc.

This discovery of growth stimulation led to treatment by similar means of tubers, shrubs, and flowering plants which appear to have only intermittent growth, and which cannot be forced, even under the most favorable conditions, to grow or blossom during their usual dormant period. Nearly 250 different chemicals were tried in various ways in an attempt to overcome this inactive stage. One of the most effective compounds was found to be ethylene chlorohydrin. By a simple treatment of potatoes with a solution of this chemical, the normal rest period of some varieties was reduced by as much as two months. Certain flowering plants, which, untreated, would not have blossomed until spring, were forced into bloom by Christmas after treatment with this agent either as a water solution or in gaseous form.

In addition to causing green-colored citrus fruits to change their hue, ethyl-

ene was found to induce root formation when growing plants were exposed to it in low concentrations. This effect was possible not only when the entire plant was exposed to the gas, but also when the ethylene was dissolved in lanolin and applied locally. In such cases, the root formation took place at the point of application. A peculiar effect of such treatment is the causing of epinasty of the treated leaves—that is, increasing the rate of growth of the upper surfaces to a greater extent than that of the lower, which results in a bending downward of these leaves.

Anesthesia of animals is well known, but this work shows that a similar effect may be obtained on plants, as well. These same gases which induce epinasty and adventitious roots also anesthetize plants. This is shown by motion pictures, which demonstrate loss of irritability and complete anesthesia, especially in the case of the sensitive plant *Mimosa pudica*.

For many years there was a belief that plants produced substances which might properly be called plant hormones. Though only assumption on his part, Sachs wrote a story in 1882 on materials which might be called flower-forming substances, etc., that fits into the ideas and findings of present-day investigators. Went and others discovered and isolated growth substances from the tips of plants. Kögl isolated hetero-auxin from urine and identified it as indoleacetic acid, a compound which has a formative effect on the growth of plants.

In most cases, the chemicals to be tested were employed as solutions in distilled water or mixtures with lanolin, but in a few instances where cuttings were involved, dilutions were made with Knop's solution. The cuttings were placed in vials or flasks so that the basal ends were immersed in the solution. The water solutions were introduced into the stems and petioles of growing plants by means of glass tubes drawn to a capillary at one end and holding approximately 0.3 cc. of solution. The capillary end of the tube was inserted into the desired portion of the plant and allowed to drain. The time required for the tubes to drain differed and the response of the plant varied with the drainage rate. Lanolin preparations were applied locally by rubbing the mixture on the stem or leaves with a glass rod.

There are now at least twenty chemicals which are known to control the growth and development of plants. They are spoken of as synthetic chemical growth substances or plant hormones. While it is not definitely known whether any of them is produced by the plant, there is strong supposition that if this is not the case, like substances are normally synthesized by the growing parts, such as tips of roots, stems, etc. Among the most effective of these are alpha-naphthalene acetic acid, indoleacetic acid, indolebutyric acid, indolepropionic acid, alpha-naphthylacetonitrile, and phenylacetic acid. Although these chemi-

FIGURE 1

Tomato plants. LEFT, *control.* RIGHT, *test plant 14 days after injecting 1% aqueous indolebutyric acid.*

cals differ individually in many respects, the responses of plants to treatment with low concentrations of them are very similar, and, furthermore, resemble those induced by the four gases previously mentioned.

The principal reactions shown by plants are local initiation of roots on stems and leaves, and local acceleration or retardation of growth, causing swelling and bending of stems. When lanolin preparations of the growth substances, in concentrations of 1 to 10 mg. per gram of the solvent, are smeared on the leaf or stem, there is immediate acceleration of local growth and, within a few days, appearance of roots from these tissues. As a rule, roots appeared on stems two to five days earlier than on petioles and more readily on older or middle-aged leaves than on younger ones. The roots formed are usually white in color and appear at an angle of 45° to the stem.

In addition to causing formation of adventitious roots, these chemicals have the property of promoting growth. Tomato plants, treated from the tip downward with a lanolin solution of any of them, showed first an acceleration and then a retardation of the elongation. At the end of five days the treated plants had elongated more than the controls. Sweet pea and Windsor bean seedlings showed an abnormal enlargement of the stem tip and retardation of the elongation, indicating increased growth in one direction and a decrease in the other. When dissolved in water and then added to the soil, the substances are absorbed by the plants, and the movement of the material can be followed by the response of the leaves and stem tissues. Within one hour after soil treatment, the plants show systemic response, indicating that the upward movement of the liquid is very rapid.

FIGURE 2

Tomato plants with tops removed. LEFT, *control.* RIGHT, *test plant 8 days after application of 1% alpha-naphthalene acetic acid in lanolin to cut surface.*

Quantitative results of the effectiveness of the different chemicals are difficult to obtain. Although it is stated generally that alpha-naphthalene acetic acid is probably the most effective, there is very little difference in the end results if the proper concentrations are compared. The indole compounds are all equally effective, although the concentrations to give best results differ.

Plant propagation is certain to be greatly aided by the use of these substances. Although hardwood cuttings have not responded as readily as the succulent types, they too are induced to produce roots more quickly than do controls. When the methods are perfected, information about them should be of great value to propagators.

A large amount of this work has been carried out at the Boyce Thompson Institute for Plant Research by P. W. Zimmerman, Frank Wilcoxon, and A. E. Hitchcock. It is through the courtesy of Dr. Zimmerman that the accompanying photographs are reproduced.

Eastman De-Ashed Gelatin in a New Form

THE Eastman grade of de-ashed gelatin No. 1099 is now supplied in a more convenient, rapidly soluble form. The new sheets, which are white, are produced by drying a gelatin foam and compressing it to a convenient thickness. Although much lower in specific gravity than the usual sheets or flakes, the pressed sheets take up no greater space because of their uniform shape.

The compressed air cells provide rapid absorption of water and accelerate its solvent action. Without being fragile or having a tendency to crumble, pressed foam gelatin can be readily disintegrated or powdered, if desired. Complete solution is obtained in about one-sixth the time required for the usual forms of gelatin.

This new material and the process used in its manufacture are described in a communication from the Kodak Research Laboratories—by S. E. Sheppard and J. H. Hudson—which appears in the April 1936 issue of INDUSTRIAL AND ENGINEERING CHEMISTRY.

New Eastman Organic Chemicals

IN accordance with the policy of continually increasing the number of purified organic chemicals available, the following have recently been added to the Eastman Organic Chemical List. All of these compounds will appear in List No. 27 which is scheduled for distribution about May 1, 1936.

3947	p-Aminoethylacetanilide MP 97-99°	100 g.	$15.00	C
3376	Benzyl p-Hydroxybenzoate MP 110-112°	500 g.	9.00	D
4154	Benzylmalonic Acid MP 119-120°	100 g.	16.00	C
P 4177	n-Butyl Crotonate (Practical) BP 175-182°	500 g.	3.00	D
P 4202	4-Chloro-2-aminoanisole (Practical) MP 80-83°	500 g.	5.00	D
P 4217	Chrysene (Practical) MP 248-250°	1 kg.	3.80	E
4019	3,5-Dinitro-o-cresol Sodium Salt	100 g.	3.00	C
4099-X	2-Ethylhexyl Phthalate	500 g.	10.00	D
3978	Ethyl n-Heptylmalonate BP 144-146°/8 mm.	100 g.	7.00	C
2371	Ethyl α-Hydroxy-iso-butyrate BP 148.5-149°	500 g.	10.00	D
P 4203	Ethyl Orthosilicate (Practical) BP 70-72°/20 mm.	1 kg.	4.50	E
4155	Ethyl-m-toluidine BP 95-97°/8 mm.	100 g.	8.00	C
2585	Glutathione	1 g.	15.00	A
4097	Methyl Furoylacetate BP 148-152°/13 mm.	100 g.	9.00	C
3554	Methyl 4-Nitrophthalate MP 66-67.5°	100 g.	6.00	C
3809	3-Nitrophthalic Acid MP 217-219°	100 g.	4.00	C
3112	4-Nitrophthalic Acid MP 164-165°	100 g.	8.00	C
4053	n-Octadecyl Alcohol MP 56.5-58°	100 g.	9.00	C
4084	n-Propylphenyl Ether BP 96-97°/35 mm.	100 g.	5.50	C
4008	1-Thiomethoxybenzothiazole MP 46-47°	100 g.	6.00	C
T 4100	α-Truxene (Technical)	500 g.	7.50	D
T 4164	β-Truxene (Technical) MP 216-219°	500 g.	8.50	D